Federal Aviation Administration

TDM-to-IP Migration

Prepared by:

FAA Telecommunications Infrastructure (FTI)-2 Program Office, AJM-3170

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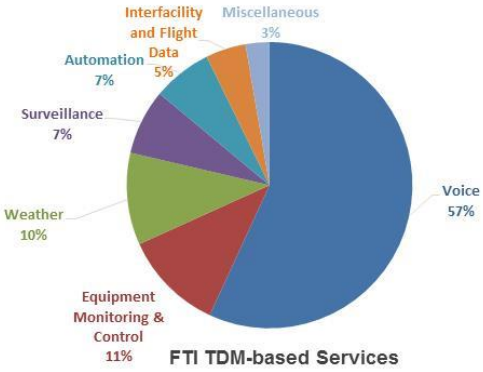
1.0 Purpose

The purpose of this paper is to provide an overview of the challenges faced by the FAA due to the phase-out by commercial carriers of telecommunications services based on Time Division Multiplexing (TDM) technology and their planned migration to services based on Internet Protocol (IP)-compatible technologies. This paper also describes ongoing and planned actions by the FAA and identifies questions that the FAA hopes to answer through its market research so that the TDM-to-IP migration does not further complicate the transition from the existing FAA Telecommunications Infrastructure (FTI) contract to the follow-on FTI-2 program.

2.0 Background

The FAA has separate network infrastructures for administrative "agency" functions such as e-mail, time reporting, etc. and operational systems that support the air traffic management functions of the National Airspace System (NAS). Administrative data exchanges are supported by the "Mission Support" network that is 100% IP-based. The NAS operational network supports a combination of TDM-based and IP-based service interfaces, but most are TDM-based due to the interface requirements of the systems that connect to the operational network. This white paper focuses on the FAA's plans for migrating TDM-based services on the NAS Operational Network.

Major U.S. telecommunications carriers have stated their intention to discontinue TDM-based services as early as 2020. The FAA is highly dependent on these services. As shown below in Figure 1, more than 90% of the 23,000+ services obtained under the FTI contract are TDM-based and support critical NAS services such as surveillance radar, air/ground voice, and interphone (ground/ground voice).



Category of TDM-Based Services	# of services
Voice (A/G, G/G, BUEC, RCO, Voice Switches)	11,921
Equipment Monitoring & Control (RMLS)	2,381
Weather (ASOS, TDWR, RVR's, IDS-R)	2,180
Surveillance (Radars, Sensor)	1,549
Automation (TAMR, STARS)	1,406
Inter-Facility and Flight Data (FDAT, IDAT, FDIO)	954
Other	566
Total	**20,957**

Figure 1. NAS Functions That Require TDM-based Telecommunications Services

While the FAA has modernization initiatives underway to reduce its dependency on TDM-based services, those initiatives are not fully funded, are not scheduled to be completed before 2020,

and do not address the full scope of communications interfaces that need to be upgraded under the telecomm carriers proposals.

It should also be noted that, while the TDM-to-IP migration by commercial carrier presents challenges for the FAA, it also presents an opportunity to migrate to a more cost-effective technology capable of supporting the NextGen concept of operations that is based on being able to dynamically reconfigure assets to balance workload across available resources. IP-based services also represent a means to improve network resiliency because of the flexibility they provide to dynamically route communications.

3.0 Summary of Carrier Actions

In November 2012, AT&T submitted a petition to the Federal Communications Commission (FCC) regarding their planned migration from TDM technology to Internet Protocol (IP)-based technology. This migration would potentially eliminate service offerings that are based on TDM technology if an equivalent service offering cannot be supported using IP-based technology.

As part of their petition, AT&T recommended that the FCC open a rulemaking proceeding to conduct trials (i.e., field tests) related to the TDM transition. This recommendation was accepted by the FCC and the initial trials will take place in Carbon Hill, Alabama and Delray Beach, Florida. Those locations do not support FTI services, but, depending on the locations where the nationwide transition starts, NAS sites could be impacted as early as FY2016.

4.0 Current Status of FAA Actions

4.1 Technical Actions

The FAA has developed a TDM-to-IP migration strategy that identifies a three-pronged approach for addressing the phase-out of TDM-based services:

1) Modernize NAS systems to support “native IP” communications;
2) Modernize the system communications interface of NAS systems to be IP-compatible as part of the standard technology refresh process; or
3) Implement one or more solution alternatives within the telecommunications network that do not require use of traditional TDM-based landline-based transmission technologies that are being phase-out by commercial carriers.

These three strategies can be applied in combination depending on the modernization status of individual NAS systems.

The FAA’s Communications, Information & Network Programs (CINP) Group has been working closely with the FTI service provider on developing network solution alternatives to traditional TDM-based landlines. Three specific solution options have been identified and have undergone preliminary (informal) testing:

1) Use of a TDM-to-IP conversion device;
2) Use of very small aperture terminal (VSAT) satellite-based services; and
3) Use of 4G Long-Term Evolution (LTE) wireless services.

The first two of these three options will continue to support a TDM-based interface on the user's side of the demarc. With respect to the third option, it represents a replacement for traditional TDM-based landline-based transmission, but it must be used in combination with TDM-to-IP conversion devices if the user does not modernize their communications interface.

The testing that has been conducted to date has shown favorable results for the first two solution options. Equipment models from multiple vendors have been tested and all appear to provide a feasible solution with minor variations in cost and performance. With respect to the 4G LTE solution, the FAA has been performing a field trial at an FAA VHF Omni-Directional Range (VOR) site that lost its landline connectivity due to a wildfire. Thus far, the FAA and the FTI service provider have been unable to achieve an acceptable level of performance, but additional strategies are being pursued to improve the performance. It is also possible that different NAS systems may be more compatible with the performance of the 4G LTE wireless service than the VOR.

For the TDM-to-IP network conversion device solution option, the FAA and the FTI service provider are planning more formal testing using the FTI National Test Bed (FNTB) at the William J. Hughes Technical Center (WJHTC) in Atlantic City, New Jersey followed by Key Site testing at representative FAA operational locations. These testing activities are planned to be completed by the end of FY2016.

4.2 Programmatic Actions

Through its participation in the Government-wide Chief Information Officer (CIO) Council (in conjunction with the Department of Transportation), the FAA has been working closely with the Office of Management and Budget (OMB) and the National Telecommunications and Information Agency (NTIA) to support their efforts to identify and assess the impacts of the TDM-to-IP migration by commercial carriers on Federal agencies. The FAA has prepared a Plan of Actions and Milestones (POA&M) that projects the budgetary impact of implementing the three-pronged strategy described in Section 4.1 of this white paper depending upon whether the phase-out of TDM-based services in the commercial market place is completed by 2020, 2025, or 2030.

The results of the FAA's time-phase analysis depicted in Figure 2 indicate that the FAA would likely have to rely heavily upon TDM-to-IP conversion devices if the phase-out must be completed by 2020, but 2025 and 2030 end dates would allow more time for system modernization. The FAA's analysis assumes that carriers will replace TDM-based access with Carrier Ethernet-based access.

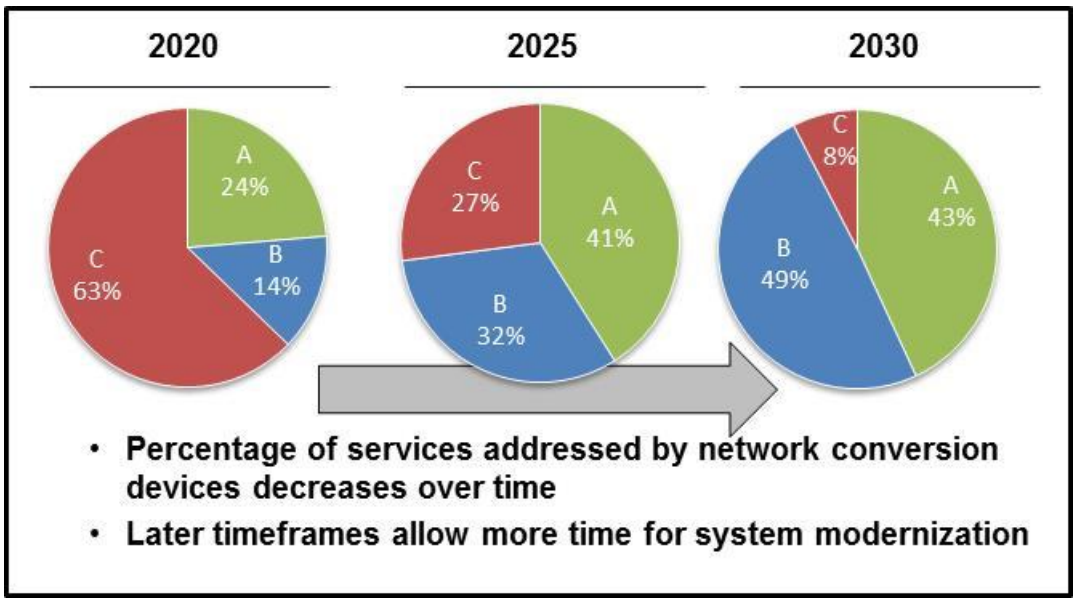


Figure 2. Outcome of FAA's Time-Phased Analysis of TDM-to-IP Migration

Note: In Figure 2, the letters A, B, and C are defined as:

A – System Modernization to Native IP,
B – Modernization of the communications interface only; and
C – Implementation of a TDM-to-IP conversion device.

The FAA has also met with the Federal Communications Commission (FCC) on three different occasions to make them aware of the potential impacts of the TDM-to-IP migration on NAS operations. This has been instrumental in steering the selection of AT&T initial trial sites to areas where there are no FAA telecommunications services. In the longer term, the FAA hopes to participate in collaborative trials with the carriers to ensure that replacement technologies are compatible with NAS systems and the TDM-to-IP conversion devices selected by the FAA and the FTI service provider.

In convert with the CINP Group's efforts, the NextGen Office (ANG) has prepared a draft policy that sets targets for when all new programs should plan on use of IP-compatible services and when existing systems should plan to migrate off TDM-based services. The draft policy is currently under review by NAS stakeholders.

5.0 Challenges Posed by the TDM-to-IP Migration

5.1 Service Performance

Many NAS applications operate natively using synchronous protocols and require a highly reliable synchronization source with exceptional stability. Without the inherent synchronous

capability of TDM-based services, NAS applications may experience out-of-sync clocks leading to buffer overflows, lost frames, and variable latency – disrupting these critical NAS applications.

The nature of IP networks with packet-based switching, dynamic routing, and application retries results in variable and non-deterministic latency. Most FAA radio communications services utilize Phase Shift Keying (PSK) to maintain connectivity between the control site and the remote radio site. PSK is very sensitive to discarded packets. While PSK has proven extremely robust under legacy analog and digital transport, when transported over IP networks a single discard of a packet transporting 20 milliseconds of audio will result in the radio being unavailable to air traffic controllers for 2-4 seconds as the link is reestablished. Thus, without the deterministic performance and reliability offered with TDM services, the FAA's National Airspace System would be degraded and put at significant risk.

The AT&T petition describes the potential for replacing traditional wireline infrastructure with wireless technologies, specifically Long-Term Evolution (LTE) services. Many NAS services, including air/ground radio, navigation, and weather equipment feeding the FAA and the National Weather Service, use analog modems. Results from the FAA's LTE access tests have shown a lack of compatibility of wireless replacement services with modem audio. In addition to the issue of modem compatibility, the use of commercial LTE services also raises concerns with respect to information security and congestion (which could lead to the services being unavailable to the FAA). As such, replacement of wireline infrastructure with wireless-only options could further impact the FAA.

Ethernet may drop packets when congestion is encountered in the network. If Ethernet is used as a transport for TDM services, dropped packets could result in a loss of synchronization for a TDM circuit implemented over Ethernet transport. Having a stable, uncongested network is a must for systems that require deterministic performance from their telecommunications services. When using Carrier Ethernet circuits to provide the "last mile" connection between the FTI network and the remote FAA facility, the performance of the service is dependent on the performance of the Carrier Ethernet network as well. This implies that performance parameters must be specified in such a way as to guarantee a congestion free path through the network. It is uncertain as to whether commercial carriers will allow the FAA to specify performance parameters such as Committed Information Rate, Class of Service, and Quality of Service to ensure compatibility with NAS systems.

5.2 Service Avoidance/Diversity

TDM circuits can be ordered with avoidance (possibly more commonly referred to as "diversity" in the telecommunications industry) by specifying the two circuit IDs that require avoidance at time of the order. The carrier then provisions each circuit on a separate and distinct path such that neither circuit utilizes the same physical cable or equipment. With Carrier Ethernet, this process is more complicated. From the last Serving Wire Center (SWC) to the FAA site,

avoidance can be guaranteed. However, once past the last SWC, the Carrier Ethernet network is typically made up of a mesh of Ethernet switches interconnected with many different circuits and the data path from one end to the other is dynamic based on various factors. This is good from a network resiliency standpoint because it provides many paths around a problem should one occur. However, it is anticipated that there will be limited visibility into the design of the Carrier Ethernet network, so the FAA will not know for certain that avoidance is being provided as required. In addition, when one carrier hands off Ethernet circuits to another carrier, avoidance needs to be maintained, which implies multiple paths between Carrier Ethernet networks. The FAA requires the same audit capability for Carrier Ethernet-based services as currently available for TDM-based services.

5.3 Information Security

TDM circuits are point-to-point connections and are isolated from other TDM circuits at Layer 1 of the OSI network model. By comparison, Carrier Ethernet is a shared, Layer 2 technology, meaning data is transmitted by multiple users over the same infrastructure and the carrier switching equipment is responsible for separating the traffic typically based on tags placed in the frame headers. In this case, frames with the same tags can be seen by all users configured to see those frames and other users cannot see those frames. One potential security issue involves misconfiguration by the carriers when the circuit is ordered. Should the carrier configure a circuit and allow traffic to be visible to users other than the ones intended, then those users would have access to view and potentially access the end devices of the other user. Other security concerns include the potential for an attack based on unauthorized access to the carrier's switching infrastructure. Aggregation of services on Carrier Ethernet present additional challenges for information security. Security vulnerabilities may have broader impacts if multiple services can be compromised with a single attack.

5.4 Programmatic Challenges

The following is a summary of challenges associated with the TDM-to-IP migration that are programmatic in nature:

- The FAA does not control where and when carriers will phase-out TDM-bases services;
- The FAA may not be able to influence carrier decisions on replacement technologies, e.g., Carrier Ethernet (more desirable) versus 4G LTE Wireless (less desirable);
- The FAA does not currently have the necessary funding to fully implement its migration strategy;
- The FAA is facing an increase to its operating costs for telecomm services due to the potential for the minimum order quantity for access bandwidth to increase from 64 kbps to 10 Mbps as carriers shift to Carrier Ethernet; and

- Portions of the FAA's migration depend on external entities such as the Department of Defense (DoD) and the National Weather Service (NWS) that have systems that interface with the NAS.

6.0 Questions

1. How will the TDM-to-IP migration potentially influence FTI-2 transition planning if the two activities overlap in time?
2. As the FAA plans for the FTI-2 program, what steps can be taken to avoid "stranded investment" in TDM-to-IP conversion devices under the FTI and FTI Bridge contracts?
3. Would it improve the competitive landscape for FTI-2 if the FAA owned or could GFE the TDM-to-IP conversion devices to the FTI-2 service provider?
4. Relative to what is currently available for TDM-based services, can the FAA expect an equivalent level of visibility into the physical configuration/routing of IP-based services?
5. Can NAS services be migrated to IP-based technologies with no adverse impacts to information security?